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ABSTRACT

This report collects together three presentations given by the author at scientific and professional meetings during the Spring of 1977. The first discusses present views of the variety and complexity of individual differences among human beings in the context of current research on cognitive processing in learning and instruction. The second section presents an eight-point outline of the nature of prescriptive instructional theory and shows how considerations of individual differences are involved at each point. The third section reviews how data on aptitude-treatment interactions can be collected and used by the instructional designer in the instructional development and revision process. (Author)

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INDIVIDUAL DIFFERENCES, INSTRUCTIONAL THEORY, AND INSTRUCTIONAL DESIGN

RICHARD E. SNOW

TECHNICAL REPORT NO. 4
APTITUDE RESEARCH PROJECT
SCHOOL OF EDUCATION
STANFORD UNIVERSITY

Sponsored by

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report collects together three presentations given by the author at scientific and professional meetings during the Spring of 1977. The first discusses present views of the variety and complexity of individual differences among human beings in the context of current research on cognitive processing in learning and instruction. It proposes that such research keep track of its relation to various types and levels of individual differences by referencing a hierarchical network of potential aptitude constructs.

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Also noted are some parallels between modern hypotheses about cognitive processing and traditional interpretations of ability test factors. The connection of each to real-world criterion performances is also discussed.

The second section presents an eight-point outline of the nature of prescriptive instructional theory and shows how considerations of individual differences are involved at each point. Examples from recent research on aptitude-treatment interactions are used to suggest how instructional theory might be pursued in local settings. The view that general instructional theory can be constructed in a top-down fashion and applied across situations and student populations is questioned. It is argued that instructional theories will likely be specific to locations and populations by research akin to formative evaluation studies, and that more general constructions will be built, if at all, on the basis of case-by-case similarity.

The third section reviews how data on aptitude-treatment interactions can be collected and used by the instructional designer in the instructional development and revision process. Recommendations are given as to what aptitude variables might routinely be included in evaluation studies, and what steps can be followed to use such data for instructional analysis.

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Preface

This report collects together for distribution three convention presentations given by the author during winter and spring, 1977. The three are complementary, though of necessity also partly redundant. The author apologizes for the latter and hopes that it aids rather than retards reading comprehension.

The first section is an elaboration of discussant remarks at the Symposium on "Individual Differences, Cognition, and Learning", American Association for the Advancement of Science, Denver, February 22, 1977. One small portion is also part of a chapter titled, "Aptitude-Treatment Interactions in Educational Research", in L. A. Pervin and M. Lewis, (Eds.) Internal and external determinants of behavior. NY: Plenum, in press.

The second paper comes from a symposium entitled, "Recent Advances in Instructional Theory", American Educational Research Association, New York, April 5, 1977. It is scheduled to appear in Educational Researcher in a fall 1977 issue.

The third paper was part of a symposium on "Excellence in Instructional Development", Association for Educational Communications and Technology, Miami, April 27, 1977. It will appear in a forthcoming issue of Journal of Instructional Development.

Over the past two decades, cognitive experimental psychology has blossomed. It is marked by the growth of interest in analyses of human information processing in perceptual, cognitive, learning, and problem-solving tasks. It has been developing increasingly sophisticated mathematical, and computer simulation models of such performances. These provide a powerful method of theorizing about complex cognitive processes, and the power of this approach is now being turned to a renewed examination of individual differences in cognition and complex learning. Of major interest in this work is the analysis of the kind of complex cognitive learning that occurs in the real world, and particularly in school and college instruction. Many leading experimental psychologists are now working at the forefront of this movement. There are many exciting possibilities and problems for current and future research. (See, e.g., Glaser, 1972, 1976; Klahr, 1976; Resnick, 1976; Rumelhart & Norman, 1976; Cole, 1977; Greeno, 1977; Hunt, 1977; Sternberg, 1977.)

One cannot hope to critique all of these important ideas in a short paper. Instead, this paper describes briefly some other views of individual differences in cognition and learning that emanate from differential psychological and educational research. This will provide a frame of reference in which to test the new ideas coming up from experimental work in cognitive psychology and to raise questions for further research and development in this field.

It is the unfortunate tendency of new scientific movements to debunk older approaches to the problems of common interest, and too often the good is thrown out with the bad. There are signs that mental tests and the tradition of educational and psychological research based on them may suffer such a fate in a new cognitive psychology of instruction. But all relevant scientific concepts and methods will need to be combined in further work, if cognitive theory is to be useful in understanding individual differences in learning from instruction, and in improving instruction thereby.

There are three main points to be addressed here. The first concerns the variety of individual differences observable among human beings and the means by which a science can hope to deal with them. The second focusses on the peculiar nature of individual differences in learning from instruction. The third suggests why mental ability tests and learning process measures may simply be different representations of the same phenomena.

First--on individual differences in general--there are literally thousands of potential individual difference variables relevant to cognition, learning, and instruction. At a relatively molar level stand dozens of ability constructs that have been demonstrated over and over again in differential psychology for decades. Verbal or crystallized ability is one such construct. Fluid-analytic ability and spatial ability are also examples. Each of these might be related at another level to a variety of information processing parameters such as those studied by Hunt (1977). At this level, however, there are hundreds of other individual differences detectable in the details of information processing in particular situations. And individuals probably differ not only in parameter measures associated with particular steps in a processing model, but also in the sequence in which several steps are taken, in the inclusion-exclusion of certain steps, and in the structural and strategic character of the whole performance. We are not likely to find one-to-one correspondences between such process differences and molar ability constructs. Process differences probably combine in complex ways to account for ability test differences. Hunt demonstrated this point; it was also nicely expressed by Herbert Simon (1976) in describing the kinds of complex performance differences observed in computer simulations that may combine to account for general intelligence differences. Also, at a still more molecular level, there is a vast jungle of biochemical and neurophysiological differences, at least some of which seem clearly relevant to psychological differences in learning and cognition. Williams (1956) argued forcefully, with many illustrations, that we are simply not "all pretty much alike under the skin." There are many more recent illustrations. And some psychobiological differences show potentially important relation to real-world learning and performance criteria as well as to aptitude test measures. (See, e.g., Rimland, 1977.)

This vast complexity of individual differences can never be covered comprehensively in theory. To deal with it at all, differential psychologists have adopted some conventions based on the principle of parsimony. Human abilities are conceived to be arranged in a hierarchy with general intelligence at the peak, divisible into more and more specific abilities and skills at successively lower levels. This allows one to choose a level of specificity to fit particular theoretical or practical needs. No one level is "correct" for all purposes. At times a few molar constructs are most useful; in other situations, finely differentiated constructs may be needed. But new constructs or interpretations are accepted only if they are empirically distinguishable from constructs already in the hierarchy. Also, constructs at any level must be demonstrable by more than one independent measure. Individual difference constructs, then, are defined by between-task-relations, not by single tasks. Newell (1973) recently decried the fact that cognitive psychology was composed of about 40 different camps, each with its own pet task. The study of individual differences forces upon cognitive psychology the rigors of construct validation. Greeno's (1977) studies of language understanding require the use of relational constructs because language processing is inherently relational. Hunt (1977) has also used multiple measurements of memory processes. But when such work seeks to connect process measures to ability constructs such as verbal ability or spatial ability, the latter constructs must also be measured in more than one way. Otherwise we cannot know whether the reported relations are only specific to one test or refer more generally to the construct. Further, we cannot interpret such findings in the hierarchy of ability organization unless we know whether the relations refer to verbal or spatial ability uniquely, or to the general intellectual component that runs through verbal and nonverbal measures alike. Individual difference variance in all psychological measures, not just in tests, can be divided into at least three kinds of components: common variance, reflecting sources of individual differences also reflected in other measures and thus generalizable beyond any particular measure; specific variance, reflecting sources of individual differences unique to a particular measure; and error variance. Efforts to identify individual differences in psychological processes operating within any measure should center on the common variance component, and must distinguish the three--common, specific, and error--to do this.

In short, research in this area needs to reference the whole network of ability relations in order to interpret particular ability-process connections.

Now to the second point. Reference was made earlier to Simon's view that the varieties of differences in simulation programs might constitute a performance description of general intelligence. But he also speculated that general mental ability might reflect "individual differences in the efficacy of the learning programs that assemble the performance programs" (Simon, 1976, p.96, emphasis added). What if general mental tests represent primarily this assembly function? Then they would correlate more with learning differences in training and educational settings and less with performance differences elsewhere in life; the more general, more complex tests would correlate with the more complex educational and training criteria. And so they do; that is what they were designed to do. Does this make them unimportant? Should scholastic aptitude tests be discarded because they predict only educational criteria strongly? While Cole's (1977) cross-cultural, cross-situational view that many kinds of real world cognitive performances need to be studied and contrasted, not just those reflected in tests, still the understanding of educational performance at all levels, both formal and informal, remains an important aspect of national and international development. Olson (See, e.g., Olson & Bruner, 1974.) defines intelligence as skill in a medium of communication. Education is a medium and general mental tests measure skill development in this medium. Television is also a medium. In Israel, there was no children's TV before "Sesame Street". Salomon (1977) demonstrated that, with such experience, certain perceptual cognitive skills measured by tests develop. His data may not be as clear as that of the Wagner data cited by Cole. But the point is clear. Different cultures and subcultures rely on different media for cognitive communication, and each medium requires a certain complex of skills for its effective use. In developed societies, formal education is one central medium, and scholastic ability tests represent a significant portion of the skills needed for use of that medium.

It should also be noted in passing that mental tests do occasionally predict performance criteria in the world outside of schools. Some of the special abilities in the hierarchical model referred to previously

were developed and validated for just such special predictions.

But Cole makes a more important point that is as relevant inside education as it is outside. It is reflected in some of Hunt's remarks as well. Particular individual differences from the vast array of possible differences come into play only upon situational demand, and situations vary substantially, intra- as well as interculturally. A large literature in educational psychology attests to the fact that individual differences in learner aptitudes predict learning outcomes. One can certainly derive from this that the overlap between the predictor tests and learning or performance criteria is only 50%. But this kind of average estimate turns out to be irrelevant because a substantial body of literature also now demonstrates that aptitude variables often interact with instructional treatment variations in these predictions. That is, different learning treatment situations place different demands on the learner. These socalled aptitude-treatment interactions have important implications for instructional theory and practice. And they are a special case of person-environment interaction in psychology generally (see e.g., Cronbach & Snow, 1977).

To give a simple schematic example, in conventional lecture-demonstration instruction in science, one will usually find a moderate correlation between mental ability at the start and achievement at the end. If one makes the instruction more inquiry-oriented, the ability-achievement correlation will usually go up. That is, higher ability students do better and lower ability students do less well, relative to conventional conditions. If, on the other hand, the instruction makes increased use of physical models and simplified, clear cut demonstrations, the ability-achievement correlation may often go down; here, lower ability students do better and higher ability students do less well, relative to their performance in conventional conditions. This sort of result has led to the hypothesis (Snow, 1977) that increasing the information processing burdens in instruction allows high students to capitalize on their ability, while overtaxing the lower ability students. Removing some of these burdens compensates for low students' weaknesses. In effect, the treatment must be made to do for these latter students what they cannot do for themselves, at least temporarily. This helps lower ability students but fails to stretch higher ability students and in the extreme bores them or interferes with their idiosyncratic processes. Such phenomena are ubiquitous in education but they are not at all well under-

stood. Obtaining such understanding requires process analyses of both aptitudes and instructional situations, and this follows directly from the admonitions that Hunt and Cole put forth.

Greeno (1977) also moves in this direction, but his work raises still another issue, which leads into the third point of this brief paper. Educational learning and perhaps most other important kinds of real-world learning) is learning over the long haul. When psychologists study learning they too often deal with very short episodes. In the Journal of Educational Psychology, for example, most articles reporting instructional experiments have studied an average learning time of about fifty minutes. Unlike learning in most laboratory tasks, which tends to be repetitive and cyclical, educational learning is cumulative, and it never starts from zero. Even in laboratory studies of understanding text, learners differ in the many details of relevant prior knowledge already stored in longterm memory. They differ further in adaptive strategies, in flexibility when changing tasks or strategies within tasks, in learning-to-learn and transfer functions, and in what Suppes (1977) calls "trajectory" over a sequence or course of instruction. Beyond this, they differ also in various predispositions, and in the tempermental and motivational concommitants of complex learning. Rumelhart and Norman (1976) recently supposed that complex learning involved three probably overlapping stages: initial knowledge acquisition, or "accretion", cognitive structuring or "restructuring", and "fine tuning". Greeno's (1977) work seems also to move into this sequence, starting with word recognition, then sentence comprehension, and on to understanding of larger bodies of text. This takes us into cognitive structuring, even though the kinds of text studied so far seem not to require restructuring or fine tuning, or to reach beyond to transfer to new material. Thus there is a long way to go before an account of educational learning can be derived from this work.

In the meantime, however, Greeno's discussion of individual differences in understanding sentences parallels some very old definitions of intelligence. (See Snow, 1976, for a summary of such definitions.) Beyond word comprehension, Greeno notes that the learner must interrelate the schemata corresponding to words in a sentence to make inferences needed to embed new terms in the conceptual network. This harks back to Spearman's definition of G as individual differences in the eduction of relations

and the eduction of correlates. Add to this Binet's emphasis on adaptation and flexibility across intellectual tasks, and it is quite reasonable that general mental ability measures should correlate with complex learning measures, and that variations in instructional demand should increase or decrease this correlation. This is not to suggest that aptitude differences in any way explain learning differences. Rather, individual differences in aptitudes and in learning differ in form, not in kind, and analyses of the sort discussed by Greeno, Hunt and Cole stand a good chance of identifying at least some of the psychological processes common to each.

Individual Differences in Instructional Theory

What place have individual differences in instructional theory? What implications for the design of instructional theories derive from research on individual differences? Not long ago such questions would have been easy to answer, for until the 1950's or so, there was no place for individual differences in theories of learning, and there was little that empirically-oriented educational researchers could call "instructional theory". Over the past two decades, however, two developments have made these questions important, if difficult, to answer.

One of these developments--the rise of a modern cognitive psychology of information processing--at last provides a rich view of human learning and problem-solving applicable to the analysis of instruction. The information processing approach offers a methodology for theorizing about the complex of cognitive machinery connecting stimulus and response, rather than simply a method for experimenting on these connections, as older psychologies did (Anderson & Bower, 1974; Estes, 1975). It incorporates the best of the neo-associationistic tradition as well. The rapid extension of this approach to the consideration of instructional theory, by Glaser (1976) and Atkinson (1972;1976) to name but two, is a welcome and exciting event. And there is now something we can at least call "steps toward instructional theory".

The other development over the past two decades has been the recognition that individual differences in aptitude not only predict learning outcome but also often interact with instructional treatment variations in so doing (Cronbach & Snow, 1977). This fact makes adaptive instruction a possibility and even a requirement for educators. It also makes the possibility of combining cognitive experimental psychology and cognitive differential psychology much more exciting, because it shows that relations among individual difference variables can be manipulated by varying treatment conditions. However, as work on aptitude-treatment interactions (ATI) has proceeded, it has become

clear that interactions, both among individual difference variables and between them and instructional conditions, can be so complex as to push generalizations beyond our grasp, practically speaking. A well known learning theorist once remarked, after one of the author's colloquium presentations on ATI, "If you're right I quit, because this makes it all too complicated--theory becomes impossible!" Cronbach (1975) was more eloquent:

> Once we attend to interactions, we enter a hall of mirrors that extends to infinity. ... not ... because human events are in principle unlawful ... [but because] we cannot store up generalizations and constructs for ultimate assembly into a network. [p. 119, 123]

That is, beyond the presently perceived complexities of ATI, there are aptitudextreatmentxdecadexlocale interactions. Without generalizations massed over time and place, we apparently cannot form behavioral laws on which to base instructional theories. Thus, in the space of 20 years, we have gone from a point where learning theory without individual differences applied to instruction hardly at all, to a point where attempts at incorporating individual differences seem to make theory impossible.

Accepting such a view this presentation could now stop short. But this researcher believes that instructional theory <u>is</u> possible in the face of individual differences. It will be a rather different sort of theory than what we usually think of as theory. ATI does not make theory impossible; it makes general theory impossible. Perhaps we already knew that general theories would never work in the diversity of education anyway. Individual difference variables operating in ATI show the essential importance of detailed description of both specific instructional situations and specific groups of people. And information processing approaches provide a means of analyzing both specific situation and specific person variables. But the kind of theories that come out of this are quite specific, limited in both time and place. These are theories that apply to the teaching of arithmetic in Grades 1-2-3 in Washington and Lincoln schools in Nutley, New Jersey, but perhaps not to the two other elementary schools

in that town; to a course in economics in a particular private high school; or to a 2-week social studies unit on alienation in a central city junior high school. The research that is done at this level is close to what would ordinarily be called "formative evaluation", and seems consistent with Cronbach's (1975) emphasis on local description. But it isn't just that. It would include iterative attempts at instructional development, and information processing experiments designed to analyze learning tasks as well, all conducted on site.

Conceivably, more general instructional theory might be reached at some future time by categorizing a large number of such specific instructional cases. Clusters of cases might become apparent in which conditions and effects were similar enough to support a within-cluster conclusion. Generalizations might emerge from experience in this way just as the therapist or counselor might reach generalizations by sorting his cases. In other words, the local theories are perhaps data points for more abstract notions. But there would never be a general, top-down instructional theory, created in academia and applicable, or inapplicable, in particular schools.

The conclusion then is that instructional theory may be possible --indeed it is well worth a try--but it should concern itself only with narrowly circumscribed local instructional situations, relatively small chunks of curriculum for relatively small segments of the educational population. Such theories would be intended to generalize more across time in one place than across places, but they would be somewhat time bound as well. They would share concepts and methodology but they would be very specific miniatures.

Let us look at what the form of one of these local instructional theories might be, to identify the points where considerations of individual differences enter. This outline relies heavily on previous discussions by Bruner (1964; 1966), Atkinson (1972) and especially Glaser (1976).

An instructional theory is

> ...prescriptive in the sense that it sets forth rules specifying the most effective way to achieve knowledge or mastery of skills. A theory of learning describes, after the fact, the conditions under which some competence is acquired. A theory of instruction is a normative theory in that it sets up criteria of performance and then specifies the conditions required for meeting them. [Glaser, 1976, p. 4].

From this derive several components of an instructional theory. To paraphrase, with some elaboration, the views of Glaser and Atkinson, eight components or steps are required. These are:

1. A theory or model of the learning process, describing how learning is presumed to take place in a given situation. There may well be more than one of these for a particular situation.

2. A specification of instructional objectives. These will usually be multiple and derived largely from value judgments made by governments, educators, parents, and learners themselves. This is one of several points at which it becomes clear that instructional theory is not science, and should not be. The linking premises that connect psychological concepts to instructional procedures require value judgments (Phillips, 1971).

3. A task analytic description of each objective, showing the state of knowledge, skill, competence, attitude, etc., to be achieved.

4. A description of the initial state of each learner when learning begins. This will need to give initial state descriptions with respect to each objective and also for any other initial state variable that can be presumed relevant to these objectives, to possible instructional processes, and to conceivable side effects of instruction (such as student dropout).

5. A specification of admissible instructional actions and conditions that can be implemented to bring about changes from initial states to desired states. This list will be limited by value judgments from the population, by previous research findings on the conditions of learning, and within these limits, by the artistic ingenuity of the educator.

6. A methodology for iterative design of assemblies of alternative instructional actions, to decide which are likely to be optimum, i.e., an optimization design.

7. Monitoring procedures that will permit instructional actions to be adapted in midstream for the purposes of quality control. Atkinson calls this a response-sensitive instructional strategy. It combines with the previous point if instructional design is thought of as taking place during instruction, but is separate if design is prior to actual instruction.

8. Assessment procedures for determining the multivariate immediate and long range outcomes, intended and unintended, of instruction. These need to be transformable to measurement scales that permit costs of instructional actions to be connected to payoffs on each instructional objective.

Now we can ask at what points individual differences come into play. How do they influence the construction, execution, and evaluation of an instructional theory? The answer seems to be that, in some sense, individual differences need to be considered at all points. But they are most prominently of concern at Points 4, 7, 8. Reconsider the eight:

1. Learning models have been developed without reference to individual differences, yet there are multiple models partly because of individual differences among investigators and perhaps also among the subjects they study. And the increasing interest in understanding the individual's cognitive processes in modern cognitive psychology leads us to expect that the models of the near future will regularly include individual difference parameters. Current research toward process analysis of aptitudes as well as learning and problem-solving seems to be coming together and should yield integrated models of learning and cognition with which instructional theory can start. But this is only a promise at this point.

2. Instructional objectives involve value judgments, and value is mainly an individual matter. Individual differences in values across educators and school communities cause variations in instructional objectives. This is one of the reasons why many local instructional theories will be needed.

3. Task analyses of competence must reach descriptions of the individual. In many educational areas, the constituents of competence vary idiosyncratically. Even when two experts know the same facts and display the same skills, they will usually have them organized differently for memory storage and retrieval, and will use them differently in problem-solving. An account of the ways individuals differ in computer simulation analyses of problem solving is instructive in this regard; (see Newell & Simon, 1972, or Snow 1976).

4. The initial state of the learner is the point at which individual differences in learner aptitudes become most important. Describing this initial state involves much more than determining what each learner already knows about the content to come. Prior knowledge is important, but beyond this there are general learning and problem-solving abilities (what used to be called "intelligence", and lately is again), various potentially relevant special skills, and some important motivational and personality traits, all of which have shown ATI. The list runs to dozens of potentially relevant aptitudes. Elsewhere some guidelines have been given on how to choose from such a list (Snow 1977 ; Cronbach & Snow, 1977), so these need not be belabored here. At least, some representation of the general mental ability construct is a must in all instructional research and evaluation. Its psychometric importance in learning from instruction has been demonstrated thousands of times, and new research is pursuing an improved information processing conception of general ability (Resnick, 1976).

5. Admissible instructional actions again involve individual differences in values. And here previous research findings are limited because of failure to evaluate alternatives in relation to individual differences. There is also the role of individual differences in teacher ingenuity to be considered. Here is perhaps the place for a famous quote from Bruner (1966). Regarding individual differences, Bruner said:

> Quite plainly, they exist in massive degree ... the fact of individual differences argues for pluralism and for an enlightened opportunism in the materials and methods of instruction ... no single ideal sequence exists for any group of children. [p. 71]

The need to include eclectic opportunistic teacher ingenuity is another argument in support of local theory.

6. Bruner's comment, backed up by a huge volume of ATI literature, argues strongly that assembling and testing alternative instructional sequences will identify no condition that is optimum for everyone. ATI methods will need to be a central part of this design research, because here is where a basic decision will need to be made concerning how many different alternative instructional sequences are needed, how much branching is useful within each instructional stream, etc.

7. Monitoring of aptitude development as well as learning during instruction is also a matter of individual differences. Individuals learn at different rates but also adapt to different instructional conditions at different rates. Shifts to new conditions may be needed at different points in instruction for different individuals. This monitoring may be done from minute to minute, as in Atkinson's computerized situation, or from month to month as in most college courses, or at some intermediate interval. In any case, it always aims, or should, at adapting instruction to individuals.

8. Finally, assessment of outcomes requires an examination of individual differences in outcome and ATI analyses using the initial state variables. This is required because the evaluation question is always, "Did the instruction work well for the students?" That is, for each student, not just for the few who stand in the vicinity of the group average. And an instructional treatment that is best on the average may still serve some students poorly.

An example or two should make these steps concrete. These are hypothetical as examples of instructional theory, but they are based on real data from ATI studies. (See Snow, 1977, for general discussion and Peterson, 1976, and Porteus, 1976, for the particulars.)

A study by Peterson was conducted with a cooperating 10th grade teacher using a 2-week unit on alienation. The teacher taught four sections, each a different way. Peterson measured general ability, anxiety, achievement via independence and achievement via conformity as aptitudes, and both knowledge and attitude as outcomes. With the knowledge criterion there were two striking ATI. It appeared that a

method in which the teacher maintained a fairly tight step-by-step control over the presentation, with clear and frequent structuring and little student participation in discussion, worked very well for students who were high ability-high anxious and/or high in achievement via conformity relative to independence (with ability and anxiety partialled out). A method in which there was little teacher structuring of this sort and little student participation (i.e., that put the student on his own) was very good for students either high in ability and low in anxiety or low in ability and high in anxiety and/or who were high in achievement via independence relative to conformity (again with ability and anxiety partialled out). This is a complicated interaction, but it makes sense and may be useful even though the attitude outcome gave nonsignificant results almost opposite in trend to those of the knowledge criterion. What kind of prescription does this suggest for the future? It is again useful to structure discussion on the above eight points.

1. There isn't much of a learning model underlying the two best treatments, but we could formulate two crude initial ones based on information processing concepts. And the results are consistent with Spielberger's (1972) anxiety theory.

2. The specification of instructional objectives is clear. There are two: knowledge and an attitude of sympathetic concern for the problem. For the example, let us assume that knowledge counts twice as much as attitude in this community, and further that knowledge of the social problems associated with alienation is relatively more important than many other objectives in social studies. Expenditure of local resources is thus justified; one cannot afford to pursue instructional theories for everything.

3. We need to conduct a more detailed task analysis of what constitutes knowledge and attitude regarding alienation. But that does not seem unmanageable in this narrow situation. It certainly would threaten to become unmanageable as soon as one attempted to generalize to the level of the district, or the state, or the nation.

4. The initial state of the learners is described by four aptitude constructs and their combinations. A diagnosis of prior knowledge should be added, but this description covers the major personal variables and accounts for a large amount of the observable individual differences in outcome.

5. The admissible instructional actions have already been specified to some extent. A videotape model was used to train the teacher, and classroom observations verified the alternative conditions. There are, however, other possible instructional arrangements to be tried.

6. The methodology for doing this might go as follows. Assign students who show extreme scores on the interacting aptitudes to one of the two conditions as specified on the basis of Peterson's results. Any student who falls in the middle range of these aptitude distributions, or for whom we are otherwise unsure about optimum placement, is then assigned randomly to one of the two remaining sections. (Recall that the teacher has four sections.) In these two sections, try out two new alternative instructional arrangements derived from different learning models. Perhaps one of these might be built for example on social learning theory, with observation of real or simulated examples of alienation and its opposite. Perhaps it would be heavily mediated by film and television samples, and include role playing. Other possibilities can be imagined. Then the four sections are run again next year.

7. Formal monitoring of knowledge acquisition or aptitude might not be necessary in this example. But formal measures, and the teacher, would be needed to do this in longer units. Attitude needs monitoring here because initial indications suggested that it seems to work in opposition to knowledge acquisition. So, a closer look at this is needed in the next run. Perhaps the teacher could collect unobtrusively some evidence to augment the attitude scales.

8. Formal assessment will need to be expanded to include follow-up of students in later sections of the course, later courses, and perhaps even in behavioral situations that are relevant to alienation as a social problem. The ceiling on present tests needs also to be examined, since optimization should not stop at an artificial ceiling.

And the cost benefit situation needs to be addressed. Note however that students are assigned to four groups anyway. The scheme simply controls that assignment. Over iterations it should develop that two or three instructional sequences could be brought close to optimum, on knowledge at least. In the Peterson data, for some students, the two treatments already are optimum if the posttests are adequate. If subsequent data continues to show different trends for attitude outcomes, perhaps alternative courses are needed here too. Parents could even choose one track that optimizes knowledge, another that optimizes attitude. Other teachers could also be brought into the picture, since there are eleven social studies sections in this particular school.

But is this an instructional theory? Is it more than formative evaluation? It does conform to the specifications for theory, even if it must iterate to optimize some streams, experiment to try out others for students who aren't best treated by the two initial alternatives, analyze to reach improved understanding of all the information processes involved, and continuously monitor, evaluate, and describe to be sure the system stays on track. The key is thus continuous formative evaluation of a system of psychological relationships evolving over time in one place. At least potentially that is a dynamic instructional theory for that place. Note also that if, by 1984 say, the population served in this school changes so that all tenth graders turn out to be high ability-high anxiety-high conformity (Orwell might have predicted this), the instructional theory does not change; rather it just prescribes that in that year everyone is taught by the same method. It also prescribes that new teachers be selected and trained in certain particular alternatives, perhaps in a vestibule training program. This would be a major improvement over today's haphazard methods in teacher education and placement.

What the theory does not do is to generalize to other schools. At most, it generalizes longitudinally, not horizontally, and it monitors the generalization. Horizontal generalization is certainly possible, as other schools or communities are found to match this one on relevant variables. But a new start is needed to evaluate the theory's functioning in a new school. Again the key is local evaluation.

Another brief example can be added to make one further point. A similar study was conducted by Porteus in two full-term courses in a private high school. One course was on economics; the other was on educational philosophy. ATI results similar to Peterson's were found in both courses. However, the interaction in economics was pronounced in the first third of the course, and gradually faded thereafter. In educational philosophy, the opposite occurred; ATI was absent at the start and became pronounced by the end of the course. This was observed because knowledge acquisition was monitored periodically through each course. It is not exactly clear what to prescribe here. It appears that two tracks are needed--early in one course and late in the other. As students near the point of diminishing or increasing returns they would be switched in or out of the two-treatment scheme. The main point is that the same individual differences operate differently as a function of subject matter and adaptation over time. This complex effect may have occurred because students perceive the courses differently; the content is perceived as structured and difficult early in economics, and late in educational philosophy. At any rate, the example does help add weight to the message that instructional theories need at least initially to be local theories by subject-matter as well as local by locale.

Prescriptive instructional theories of this sort will always be incomplete. They will likely evolve with the locale, and they will not be sufficiently explanatory for scientific taste. One should not take from this discussion the impression that individual differences in aptitudes explain instructional processes and effects. Understanding is aided by including aptitudes, but aptitudes are not themselves well understood. A process theory of aptitude is needed. ATI research and the new cognitive psychology of information processing have come along together at just the right time to be combined with great profit. But the profit is in coordinated concepts and methodology applied in specific instructional design and evaluation settings. General instructional theory, I think, is a holy grail.

One of the oldest facts about human learning in educational settings is that individuals differ, profoundly and multiply, in how they learn. Individual differences in school learning have been apparent since Greco-Roman times, but it is only in recent years (perhaps the last decade or so) that research has begun to show the real significance of this fact for education. Until now, information about individual differences has been used in education primarily to select people out, that is, to reject college applicants, or to identify students needing slower or special education, which often turns out to be no education at all.

However, three points about individual differences in learning from instruction now seem clear:

1. Individual differences are far more complex than the single rank order conception of intelligence usually manifest in popular personal thinking, and they are also more fundamental as human characteristics than usually assumed in popular social and educational policy.

2. Individual differences in various aptitudes not only predict individual differences in learning outcome; they also interact with alternative instructional treatments. That is, they relate differently to learning outcome under different instructional presentations or methods. This kind of interaction between individual differences and instructional conditions is called "ATI", standing for "aptitude-treatment interaction".

3. Individual differences (and ATI) can be used by the instructional developer to understand and improve instruction for everyone.

First, the popular misconception that biological differences do not exist and psychological differences can be easily erased is partly our own fault as instructional communicators. It stems in part from plagiarism among educational illustrators and audiovisualists. Roger Williams (1956; 1967) stressed this point some years ago, but little notice seems to have been taken of it. He showed pictures of a variety of normal stomachs, for example, compared with a typical textbook version. Medical illustrators rarely show this kind of range of individual differences; when asked to make

a new picture of a stomach for some instructional purpose, they just copy from existing textbooks. It is a bit frightening to think that our conception of the human stomach may be based on the shape of the stomach of a single 17th century murderer. Williams gives many other examples of striking individual differences in livers, kidneys, heart and brain tissue, nerve cells, spirograms, blood chemistries, etc. Beyond this, there are now bits of evidence of correlations between biological and psychological measures. One, noted by Cattell (1971) for instance, is between measured intelligence and cortical evoked potential of the brain. Time in milliseconds from onset of the stimulus to the third wave crest is simply and inversely related to IQ. Rimland (1977) has recently noted several other psychobiological correlates.

In short, people are not created equal biologically or psychologically. It is their right to equal opportunity to learn, among other things, in spite of individual differences, that is created. And this makes adaptation of instruction to individual differences among students an imperative. Instructional development thus needs to aim at particular kinds of students, not at the mythical average student.

Now to the second point. Although all of the possibly thousands of individual difference variables are not relevant to instruction, some consistently correlate with learning and also give consistent ATI results. If ATI can be captured and understood, they will make possible the design of adaptive instruction. Only rarely, however, are these underlying ATI ideas properly evaluated in work on individualized instruction. All attempts to individualize instruction, it turns out, rest explicitly or implicitly on some kind of ATI idea.

But what does an ATI look like and how do we find one? Figure 1a shows the traditional outcome of instructional development attempts. Instructional Treatment A is judged better than B because average student achievement is higher after A than after B. A and B could be alternative instructional methods or media, or A and B might represent average effectiveness of the same course, film, program, textbook etc., both before and after some instructional development work. Student individual differences are not considered here.

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Insert Figure 1 about here

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Adding student aptitude scores (Figure 1b) gives the traditional picture an abscissa. Now we have a regression line, that is, a running average, showing the learning outcome level attained by students who come into instruction at different levels of aptitude. Pretest measures of general mental ability and of prior knowledge often give this kind of positive slope in conventional instruction. It is obtained simply by measuring an aptitude before instruction, achievement or some other valued outcome afterward, and then plotting each student as a point in the graph using his or her two scores. The line can be thought of as the running average across different aptitude levels, but it is usually estimated statistically. When results look like this, attempts at instructional improvement should concentrate on the lower aptitude students, i.e., the question is: What instructional changes will improve things <u>for them</u> particularly? It is possible that iterative instructional developments might raise the low end of the regression line, realizing more learning for the lower aptitude students while maintaining a high level of learning for high aptitude students.

But much research now suggests that Figure 1c is the more likely result. A new and different instructional treatment often gives a regression line that is sloped differently, even crossing the line for the first treatment. By improving instruction for one kind of student we have reduced its effectiveness for another kind of student. This happens often enough to suggest, only partly in jest, a first law of conservation of instructional effectiveness. It goes like this: "No matter how you try to make instruction better for someone, you will make it worse for someone else." Findings of this sort indicate ATI. If further attempts at instructional improvement fail to change this pattern, then the best one can do is to assign higher aptitude students to Treatment A and lower aptitude students to Treatment B. The two kinds of students do best with different instruction. This sort of adaptive classification of students into different instructional treatments is one important form of instructional development that can come from investigating student differences. And there are many variations on this theme.

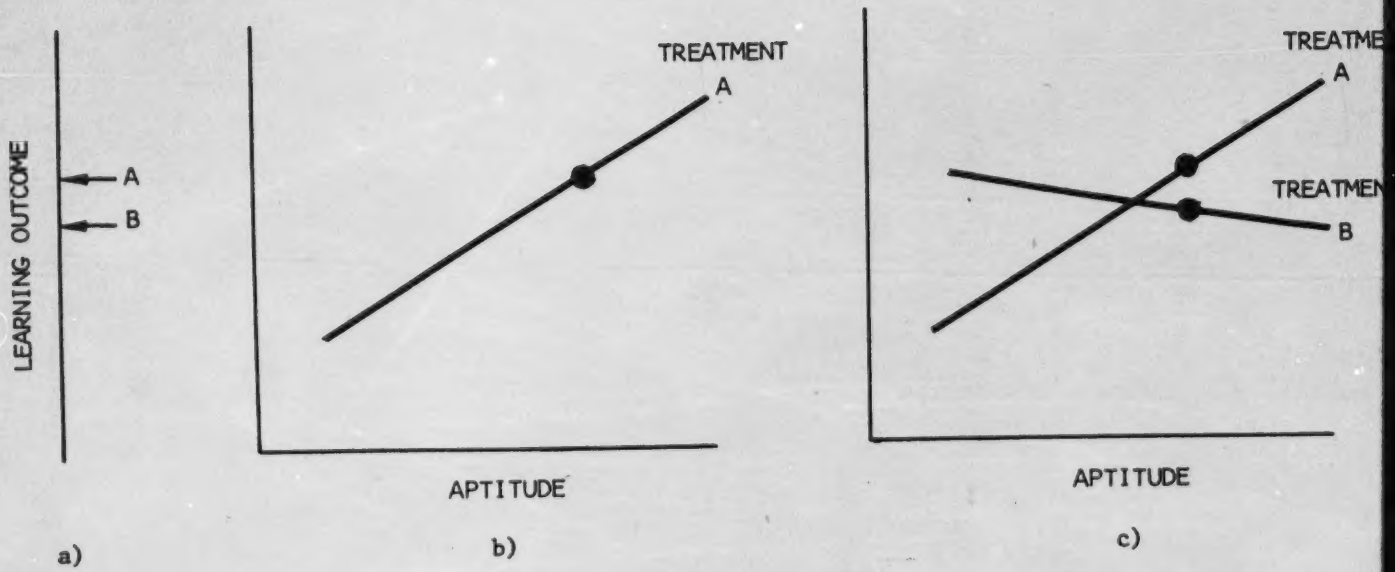

Figure 1. Hypothetical results of a) traditional instructional comparisons, b) studies including and aptitude variable, and c) studies testing for aptitude-treatment interaction.

including periodic aptitude monitoring during instruction to decide when to switch each student from Treatment B to Treatment A as aptitude develops or knowledge accumulates. One can even imagine local instructional theories (See pp. 8-18) built on such results, after much more research is done to understand the ATI phenomenon fully.

But the instructional designer-developer does not need to wait for an instructional theory of individual differences. His work can even be instrumental in creating such a theory. And this leads into the third and main point of this paper. Enough is now known about individual differences in aptitude and learning to allow the instructional developer to use individual differences to advantage in any instructional development project. At least three steps can be taken in such a project.

The first step would be to choose measures of the most important student aptitudes, based on the accumulated ATI literature as well as on whatever hunches are available about the kinds of students who seem to do well or poorly in the particular instructional condition of interest. A recent book (Cronbach & Snow, 1977; see also Snow, 1977) that summarizes much of the voluminous ATI literature could serve as one guide, but there are several other summaries as well. The aptitude variables recommended for measurement at the start of almost any kind of high school or college instruction are the following:

G is a measure of general mental ability, otherwise known as intelligence (and sometimes divided into fluid, crystallized and visualization ability; see Horn, 1976). G seems to relate to learning increasingly as more of the information processing burden of learning is placed on the student. As the treatment is made to do things for the student that he cannot do for himself, G relations are often reduced. No instructional designer should today fail to include a measure of G in a formative or summative evaluation study, because instructional conditions almost always vary in cognitive processing demand.

A_i+A_c stands for general achievement motivation or orientation, but the distinction between its two parts may be more important. A_i-A_c is achievement via independence vs. achievement via conformity. Many instructional treatments vary in the degree to which they encourage independent student action vs. conformity to instructor-set norms. Relative need for one or the other often turns out to be a critical student difference, particularly at the college level.

A_x is anxiety, another student difference that seems to be fundamentally involved in learning, both on its own and in combination with G. That is, there are higher-order ATI between A_x, G, and Treatment.

These four aptitude constructs deserve to be included in all instructional evaluations. Measures exist for each, and test administration time totals about one to two hours. There are also other individual differences of special interest. Among these are: MS (memory span), PS (perceptual speed), MV (visual memory), and CS (for various undifferentiated cognitive style measures). These aptitude variables may be important for some kinds of instruction; they deserve attention, but are optional in this general list.

Finally, a measure of prior achievement is obviously a requirement; one simply has to know what students already know, in order to develop instruction further. These measures may be pretests specific to the content to be taught, or they may be measures reflecting achievement in earlier courses, or even past grade-point-averages. One would hope, in any event, that they reflected not only variations in factual knowledge but in knowledge organization. All such differences in prior knowledge are differences in aptitude.

These are recommendations, but it should be clear that they are only hypotheses. While supported by some strong prior research, they remain to be tested anew in each new instructional situation. For reasons too numerous to detail here, generalizations across diverse instructional settings are difficult, perhaps even impossible to make. Nor should measures of such aptitudes be taken blindly. While measures of G and A_x have been fairly well-developed, any specific test may not always fit the student population of local interest. Measures of A_i and A_x have seen less development and validation, and are thus even less trustworthy. But progress should come from cautious iterative exploration. One should not throw out an aptitude measure after a single failure, nor should one institute a rigid instructional prescription after a single success.

The second step is to evaluate instructional effects by drawing scatterplots and regression lines as demonstrated earlier, to determine which students do well and which students do not in a given condition. Take each aptitude-outcome pair and investigate it separately as before. Or, use two or more aptitudes at once in multiple regression. Statistical methods for this are discussed by Cronbach and Snow (1977).

Some example pictures of results involving two aptitudes in each of two or more instructional treatments are given in Snow (1977) and so are not reproduced here. Each shows a bivariate regression plane for G and A_x, or for $A_i + A_c$ and $A_i - A_c$, as joint predictors of achievement in each of several treatments. The findings represented are those of Peterson (1976) and Porteus (1976). They are complicated, but they do make sense. The results suggest that high school students who are able, conforming and anxious, seem to need more step-by-step structure in the progress of instruction. They do better when teachers provide explicit objectives and sequences of instruction, with clear outlines, reviews, and emphases of the essentials. Students who are able, independent, and nonanxious seem to need less teacher structure of this sort. They seem to provide their own organization for learning. So also, apparently, do less able students who can nonetheless work on their own and are motivated (anxious) to do so.

Consider a hypothetical next step now. Suppose that an instructional designer pursues these earlier findings, administering the same aptitude measures in evaluating a new audio-visual tutorial course in college science. A study is conducted in which the new course is compared with the conventional lecture-demonstration format. Some student sections receive the individualized treatment, going to stalls in the AV library for work with films, tapes, and slides to guide their own study and lab work. Others get the regular treatment. (Or perhaps aptitude and outcome data are available from the conventional treatment of previous years.)

Figures 2 and 3 give the hypothetical results. The ordinate in each case is end-of-course achievement. The aptitudes in Figure 2 are $A_i + A_c$ and $A_i - A_c$; in Figure 3, they are G and A_x. Comparison with the previous results shows our instructional developer that his data in the first figure conform closely to Peterson's (1976) and those of the second are only slightly different from some of Porteus's (1976).

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Insert Figures 2 and 3 about here

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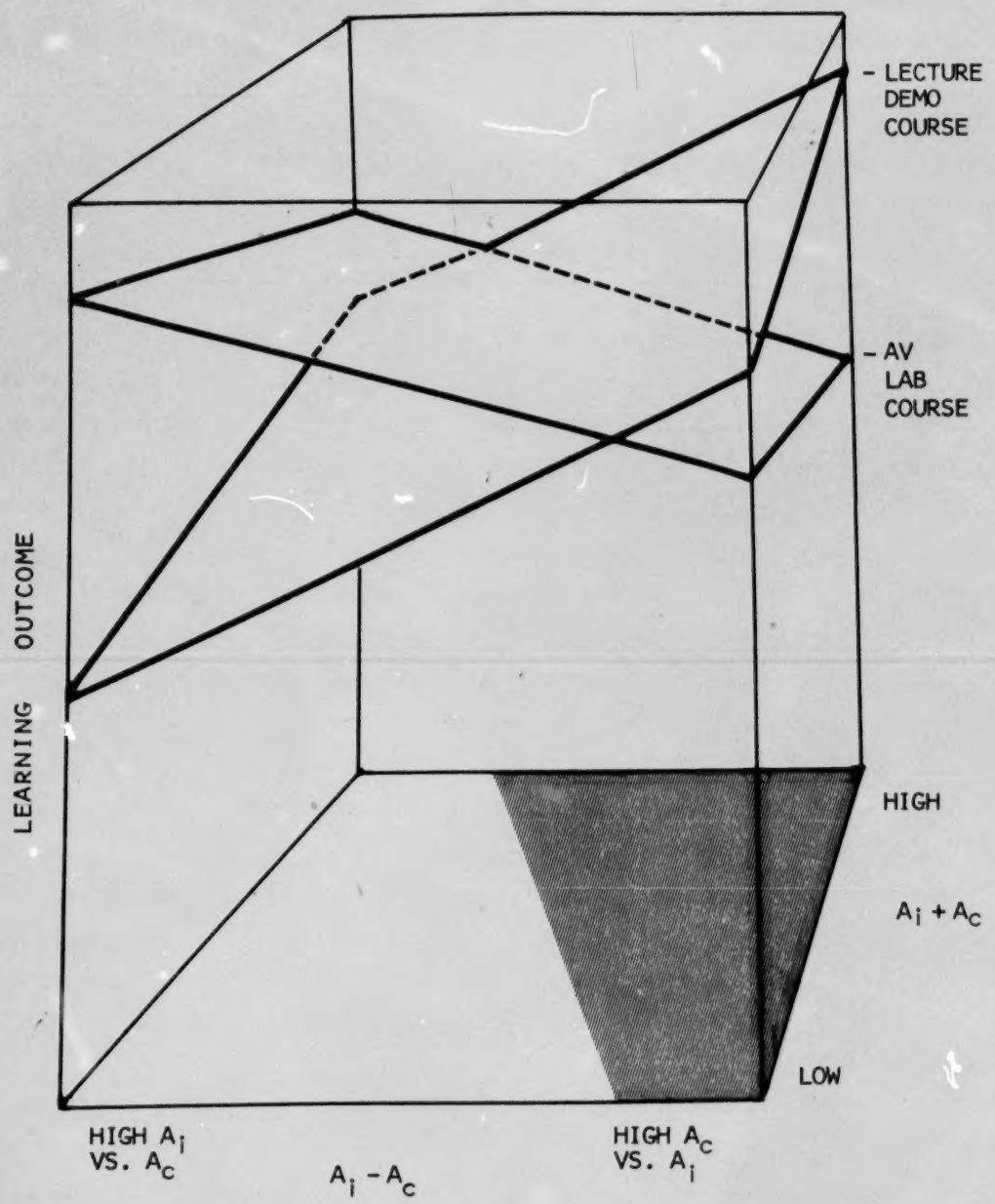

Figure 2. Hypothetical results of a comparison between a conventional treatment and a new audiovisual laboratory treatment, showing a bivariate regression plane for each treatment, with A_i+A_c and A_i-A_c as aptitudes.

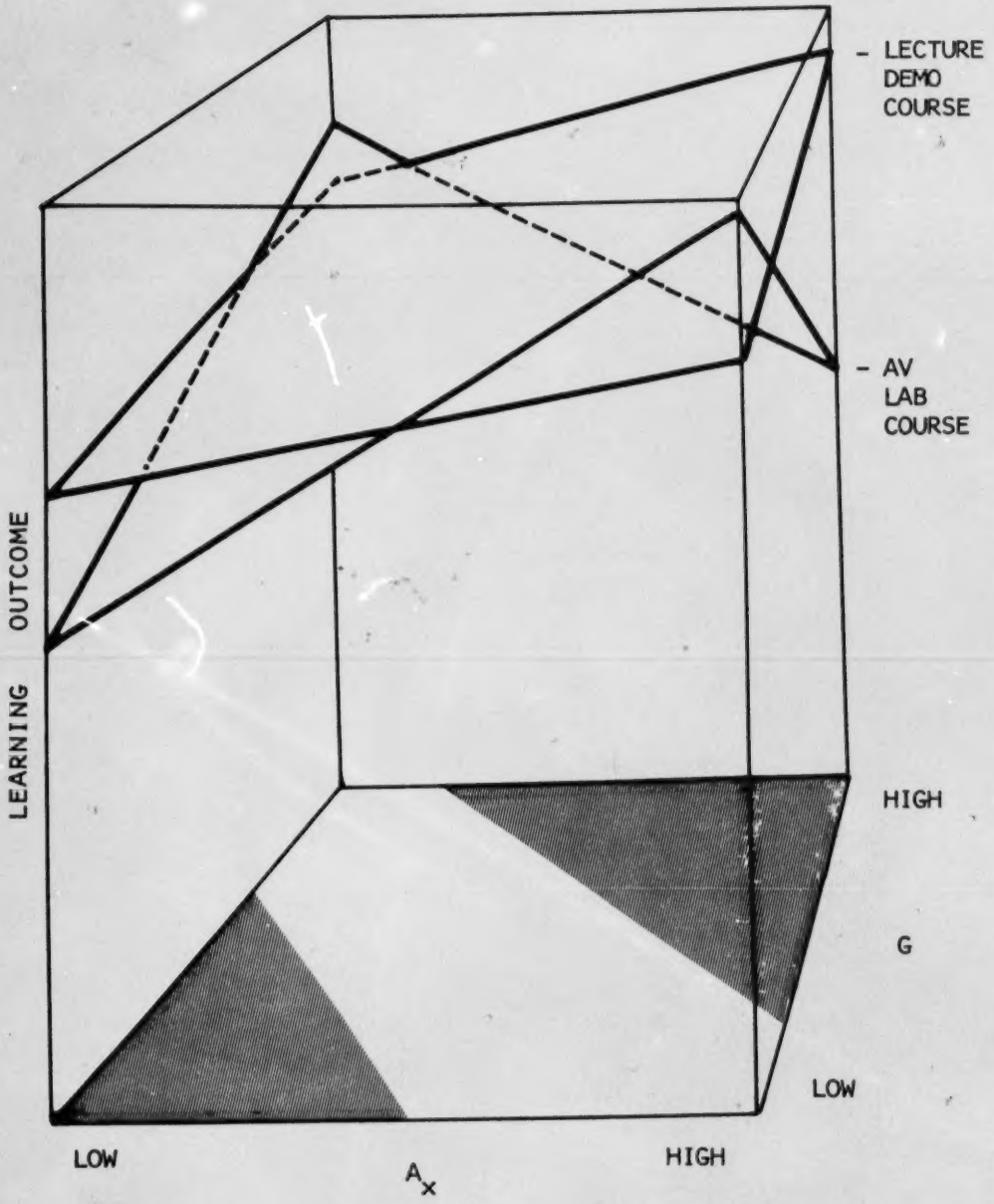

Figure 3. Hypothetical results of a comparison between a conventional treatment and a new audiovisual laboratory treatment, showing a bivariate regression plane for each treatment, with G and A_x as aptitudes.

With these results, one might think of establishing both kinds of courses and assigning students to whichever course their aptitude scores suggest will be best for them. But our instructional developer is mainly interested in improving the new course. The ATI results also give clues to help understand instructional effects because they focus attention on particular kinds of students who seem not to be well served by some particular condition. Why is the new course not effective for students high in achievement via conformity or either low or high on both ability and anxiety? Students in these groups have aptitude scores falling in the shaded regions of the aptitude base planes of Figures 2 and 3. Notice that in these regions the traditional course is better (higher) than the new course on the achievement outcome. Task analysis can then focus on these groups, and on the parts of instruction that give them trouble. We might for example ask students with these particular aptitude profiles what aspects of instruction bothered them or were helpful. Or we might observe them at work, or conduct item analyses of criterion tests separately in each aptitude group, to identify weak features of the course. Then we can tinker with these aspects of instruction during the revision process. It might turn out that conforming students need a more detailed procedural outline to follow in the AV lab, that able but anxious students need more clearly specified objectives for their individual work, and that less able, nonanxious students need to be checked frequently by a lab assistant to motivate progress. Making such revisions might erase the ATI effects, or perhaps further revisions will be suggested by ATI in further tryouts. Bunderson (1969) suggested this approach, and has used ATI this way in revising computer-assisted instructional programs. But aptitude-focussed task analysis of this sort has not yet seen wide use. This then completes the third step--diagnosis of individual difference effects and focussed revision of instruction with these effects as guide.

To summarize, one can use ATI to develop macroadaptations of instruction, assigning different kinds of students to different treatments aimed at the same outcome goal. Treatments are then designed on broadly different models to fit different classes of students optimally. Or, one can use aptitude information to make microadaptations by tinkering with aspects of one treatment during revision, so that it becomes individualized more on a day-to-day or even minute-to-minute level, as is possible in computerized instruction. Or one can do both; microadaptation can proceed within broadly differentiated streams at the macro level. In any event, what I believe one must do is to

collect and use aptitude information in all instructional evaluations. This is required because the evaluation question is always--did the instruction work well for the students, that is, for each student, not just for the few who stand in the vicinity of the group average. And an instructional treatment that is best on the average may still serve some students poorly. One can choose to ignore student individual differences, but they will be there influencing instructional effects whether they are measured and used or not. Despite the fact that education is ultimately an aptitude development program, individual differences in aptitudes will never go away.

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